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Mosquito Species Composition and Resting Distribution in Kuri and Kwadon, Gombe State, Nigeria: Implications within a Changing Climatic Environment

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ABSTRACT
Mosquito species composition, physiological status and resting behavior provide important information for understanding vector ecology and malaria transmission. This study assessed mosquito species composition, physiological status, and indoor and outdoor resting distribution in Kuri and Kwadon, Gombe State, Nigeria, and considered their implications within a changing climatic environment. Adult mosquitoes were collected from indoor and outdoor resting sites and identified using morphological characteristics. Specimens were classified as unfed, blood-fed, half-gravid, gravid, or male. A total of 778 mosquitoes were collected in Kuri, comprising *Anopheles gambiae* s.l. (45.4%), *Culex quinquefasciatus* (50.5%), and *Aedes aegypti* (4.1%). In Kwadon, 1,037 mosquitoes were collected, comprising *An. gambiae* s.l. (29.6%), *C. quinquefasciatus* (61.4%), and *Ae. aegypti* (9.0%). Species abundance differed significantly in Kuri ($F = 12.42$, $p = 0.008$) and Kwadon ($F = 9.85$, $p = 0.012$). Indoor collections were significantly higher than outdoor collections in both Kuri ($t = 3.24$, $p = 0.048$) and Kwadon ($t = 2.58$, $p = 0.046$). Blood-fed and gravid females indicated active feeding and reproductive activity. Climatic variables were not measured in this study; the climatic context discussed is therefore drawn from previously published evidence of changing temperature and rainfall patterns in North-Eastern Nigeria and is not a finding of the present data. The findings highlight the need for continued community-level entomological surveillance and climate-informed vector-control planning in the study area.

Keywords: *Anopheles gambiae*, *Culex quinquefasciatus*, *Aedes aegypti*, Mosquito Ecology, Resting Behaviour, Malaria Vectors and Climate Change

INTRODUCTION

According to the World Health Organization (WHO, 2025), mosquitoes are important vectors of malaria and other vector-borne diseases, and their epidemiological importance is closely associated with abundance, behavior, survival and reproductive activity. Information on mosquito species composition, physiological status and resting distribution is therefore important for entomological surveillance and vector-control planning (Obembe et al., 2024). Members of the *Anopheles gambiae* complex are among the principal malaria vectors in sub-Saharan Africa and are widely distributed in Nigeria (Obembe et al., 2024). Recent research in Osun State confirmed the occurrence of *An. gambiae* s.l. and showed that environmental variables, particularly temperature-related variables, contributed to its distribution (Adeleke et al., 2025).

Resting behavior is an important component of mosquito ecology because adult mosquitoes may occur in indoor- or outdoor-resting populations. Consequently, different collection methods are required to adequately characterize mosquito populations in different resting locations (Degefa et al., 2024). Nigeria has also established a national malaria vector surveillance framework that supports monitoring of mosquito abundance and insecticide resistance for planning and evaluating vector-control interventions (Obembe et al., 2024).

The physiological condition of female mosquitoes provides additional information on feeding and reproductive activity. Unfed, blood-fed, half-gravid and gravid females represent different stages of the gonotrophic cycle and can therefore help describe the structure and activity of mosquito populations (Theodoridis & Carvalho, 2025). Environmental conditions also influence mosquito abundance and distribution. Temperature affects mosquito development, survival and reproduction, while rainfall influences the availability and persistence of aquatic breeding habitats (Bello et al., 2025). These relationships may, however, vary locally because excessive rainfall can also reduce immature mosquito populations by flushing breeding habitats (Bello et al., 2025).

Recent evidence from Nigeria demonstrates the importance of local climatic conditions in mosquito ecology. Living-Jamala et al. (2024) reported associations between climatic factors and indoor mosquito abundance in Rivers State, while Bello et al. (2025) found relationships between meteorological variables and *Anopheles* larval occurrence in Lagos State. In North-Eastern Nigeria, long-term analysis has shown increasing maximum temperature and spatial variation in rainfall trends, including an increasing rainfall trend at Gombe (Ishaku et al., 2024). These observations are relevant because climatic changes can alter mosquito distribution and malaria transmission, although the magnitude and direction of these effects differ geographically and among mosquito species (Chapoterera et al., 2025; van der Deure et al., 2025). Recent modelling has similarly shown that temperature and extreme precipitation can produce contrasting effects on malaria across African regions, including West Africa (Carlson et al., 2026).

Despite the importance of mosquito surveillance for understanding local vector ecology, community-level information on mosquito species composition, physiological status and indoor-outdoor resting distribution remains limited in Gombe State. In particular, limited evidence is available comparing these characteristics between neighboring communities under similar regional climatic conditions. Such information is important because differences in species composition and resting behavior may influence the interpretation of vector-control strategies and the selection of appropriate surveillance methods. This study therefore assessed mosquito species composition, physiological status and resting distribution in Kuri and Kwadon, Gombe State, Nigeria, and considered the implications of the findings for mosquito surveillance and malaria control within a changing climatic environment.

Therefore, this study aimed to determine the species composition of adult mosquitoes in Kuri and Kwadon, describe their physiological status, compare indoor and outdoor resting distributions, and discuss the implications of the observed entomological patterns within the broader climatic context of North-Eastern Nigeria. It was hypothesized that *Culex quinquefasciatus* and *Anopheles gambiae* s.l. would be the dominant mosquito taxa in both communities, that mosquito abundance would differ significantly among species, and that indoor-resting mosquitoes would be significantly more abundant than outdoor-resting mosquitoes in both Kuri and Kwadon.

MATERIALS AND METHODS

Study Area

The study was conducted in Kuri and Kwadon communities in Gombe State, North-Eastern Nigeria. The two communities were selected as the study locations for comparative assessment of mosquito species composition, physiological status and resting distribution. The area experiences a tropical savanna climate characterized by distinct wet and dry seasons, with seasonal variation in rainfall and temperature that can influence the availability of temporary aquatic habitats for mosquito development. The region is characterized by a tropical savanna climate with distinct wet and dry seasons. Seasonal rainfall and temperature influence the availability of surface water and temporary aquatic habitats suitable for mosquito development (Ishaku et al., 2024).

Study Design and Mosquito Collection

A comparative cross-sectional entomological survey was conducted in Kuri and Kwadon to determine mosquito species composition, physiological status and indoor and outdoor resting distribution. Adult mosquitoes were sampled from both indoor and outdoor resting sites in the selected households and their immediate surroundings. Indoor-resting mosquitoes were collected using the pyrethrum spray catch method, while outdoor-resting mosquitoes were collected from suitable sheltered resting sites around houses and their immediate surroundings using an aspirator, both according to WHO guidelines (WHO, 2024). Sampling was conducted during the defined study period, with indoor and outdoor collections recorded separately to permit comparison of resting distribution and species composition.

Identification of Mosquitoes

Collected mosquitoes were transported to the laboratory for sorting and identification. Collected mosquitoes were sorted and examined under a stereomicroscope. Identification was based on external morphological characteristics using standard mosquito taxonomic keys. Specimens were classified to the lowest taxonomic level supported by the morphological characteristics available, with Anopheles gambiae s.l. reported at the species-complex level.

Determination of Physiological Status

The physiological status of collected mosquitoes was determined to provide an indication of their feeding and reproductive condition at the time of collection. Female mosquitoes were classified according to the physical condition of their abdomen, while males were identified based on their characteristic morphological features. Females were classed as unfed when the abdomen had no visible blood meal, blood-fed when the abdomen contained a visible blood meal, half-gravid when the abdomen was enlarged as developing eggs became apparent, and gravid when the abdomen was enlarged with mature eggs, while males were identified by their characteristic plumose antennae and other male morphological features.

Climate Context

Climate variables were not directly measured during the mosquito collection period and were therefore not included as statistical predictors of mosquito abundance. Published climatic evidence from North-Eastern Nigeria was used only to provide regional context for interpreting the observed mosquito patterns. Consequently, the present study does not establish a direct statistical relationship between climatic variables and mosquito abundance. Climate was therefore treated as contextual information rather than as a directly measured predictor of mosquito abundance. Published climatic evidence for North-Eastern Nigeria was used to interpret the findings. Ishaku et al. (2024) analyzed 41 years of rainfall and temperature data across North-Eastern Nigeria and reported significant increases in maximum temperature and spatial variation in rainfall trends. Evidence from other Nigerian studies also demonstrates relationships between meteorological variables and mosquito abundance (Bello et al., 2025). Similarly, Symons et al. (2026) demonstrated similar findings in the African context.

Data Analysis

Mosquito counts were entered into a data sheet and analyzed using descriptive and inferential statistics. Frequencies and percentages were used to describe species composition and physiological status, and relative abundance was calculated as (number of mosquitoes of a particular species / total number of mosquitoes collected) × 100. Inferential tests were applied to compare mosquito abundance among species and between indoor and outdoor resting locations. Prior to parametric testing, the assumptions of normality and homogeneity of variance were assessed. Statistical significance was evaluated at $\alpha = 0.05$ ($p < 0.05$), and effect estimates were reported alongside p-values where applicable. Analyses were performed using IBM SPSS Statistics version 28.

RESULTS AND DISCUSSION

Species Composition and Physiological Status of Mosquitoes in Kuri

A total of 778 mosquitoes were collected in Kuri. *Culex quinquefasciatus* was the most abundant taxon, with 393 individuals (50.5%), followed by *Anopheles gambiae* s.l. with 353 individuals (45.4%). *Aedes aegypti* was the least abundant, with 32 individuals (4.1%). Of the total collection, 395 mosquitoes were unfed, 68 were blood-fed, 61 were half-gravid, 222 were gravid and 32 were males. *Anopheles*

gambiae s.l. comprised 185 unfed, 18 blood-fed, 20 half-gravid, 114 gravid and 16 males. *Culex quinquefasciatus* comprised 196 unfed, 45 blood-fed, 39 half-gravid, 102 gravid and 11 males. *Aedes aegypti* comprised 14 unfed, 5 blood-fed, 2 half-gravid, 6 gravid and 5 males. There was a statistically significant difference in mosquito species abundance in Kuri ($F = 12.42$, $df = 2, 6$, $p = 0.008$). Figure 1 shows the mosquito species composition in Kuri, where *Culex quinquefasciatus* (50.5%) was the most abundant species, followed by *Anopheles gambiae* s.l. (45.4%) and *Aedes aegypti* (4.1%)

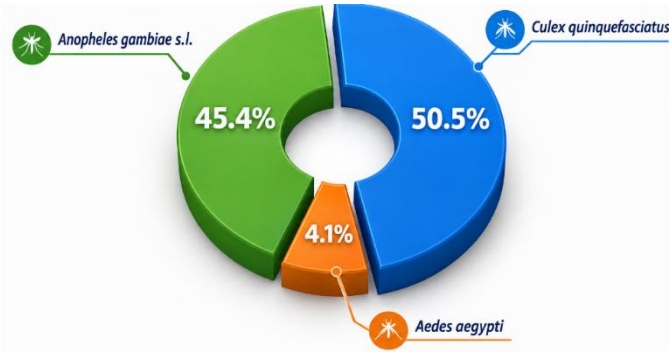


Figure 1: Mosquito species composition in Kuri

Species composition and physiological status of mosquitoes in Kwadon. A total of 1,037 mosquitoes were collected in Kwadon. *Culex quinquefasciatus* was the most abundant species, with 637 individuals (61.4%), followed by *Anopheles gambiae* s.l. with 307 individuals (29.6%). *Aedes aegypti* accounted for 93 individuals (9.0%). Species abundance differed significantly among the three mosquito taxa ($F = 9.85$, $df = 2, 6$, $p = 0.012$). Across the two communities, *C. quinquefasciatus* was the predominant species, accounting for 50.5% of mosquitoes in Kuri and 61.4% in Kwadon, whereas *An. gambiae* s.l. represented 45.4% and 29.6%, respectively. *Ae. aegypti* remained the least abundant species in both locations (4.1% in Kuri and 9.0% in Kwadon) presented in Figure 2. While The mosquito species and their physiological status recorded in Kuri are presented in Table 1. The table summarizes the number and proportion of *Anopheles gambiae* s.l., *Culex quinquefasciatus*, and *Aedes aegypti* according to their physiological condition.

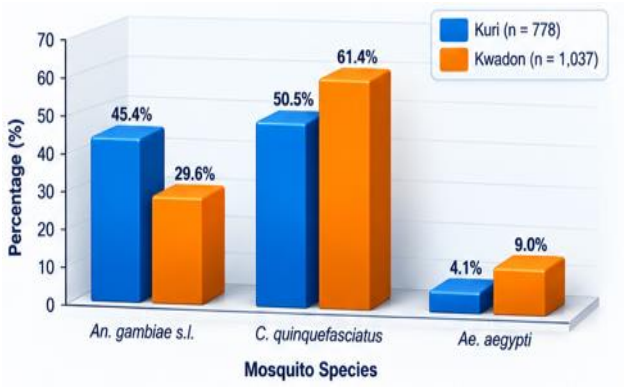


Figure 2: Comparison of mosquito species composition in Kuri and Kwadon, Gombe State, Nigeria. Values are expressed as percentages of the total mosquitoes collected at each location

Table 1: Species Composition and Physiological Status of Mosquitoes Collected in Kuri

Species	Unfed	Blood-fed	Half-gravid	Gravid	Male	Total	Relative Abundance (%)
Anopheles gambiae s.l.	185	18	20	114	16	353	45.4
Culex quinquefasciatus	196	45	39	102	11	393	50.5
Aedes aegypti	14	5	2	6	5	32	4.1
Total	395	68	61	222	32	778	100.0

ANOVA: $F = 12.42$, $df = 2, 6$, $p = 0.008$

Indoor and Outdoor Resting Distribution in Kuri

A total of 700 mosquitoes were collected indoors compared with 78 outdoors. Indoor collections consisted of 321 *An. gambiae* s.l., 358 *C. quinquefasciatus* and 21 *Ae. aegypti*. Outdoor collections consisted of 32 *An. gambiae* s.l., 35 *C. quinquefasciatus* and 11 *Ae. aegypti*. The mean mosquito abundance was 233.3 ± 181.1 indoors and 26.0 ± 13.1 outdoors. The difference between indoor and outdoor abundance was statistically significant ($t = 3.24$, $p = 0.048$). Figure 3 presents the indoor and outdoor resting distribution of mosquitoes in Kuri and Kwadon, with indoor collections substantially exceeding outdoor collections in both

communities and the distribution of mosquitoes according to indoor and outdoor resting locations in Kuri is presented in Table 2. The table compares the recorded abundance and mean number of mosquitoes collected from indoor and outdoor resting sites.



Figure 3: Indoor and outdoor resting distribution of mosquitoes in Kuri and Kwadon,

Table 2: Comparison of Indoor and Outdoor Resting Mosquito Abundance in Kuri

Species	Indoor	Outdoor
Anopheles gambiae s.l.	321	32
Culex quinquefasciatus	358	35
Aedes aegypti	21	11
Total	700	78
Mean ± SD	233.3 ± 181.1	26.0 ± 13.1

t = 3.24, p = 0.048

Species Composition and Physiological Status of Mosquitoes in Kwadon

The species composition and physiological status of mosquitoes collected in Kwadon are presented in Table 3. The table shows the distribution of the three identified mosquito taxa across the different physiological categories. A total of 1,037 mosquitoes were collected in Kwadon. *Culex quinquefasciatus* was the most abundant species, with 637 individuals (61.4%), followed by *Anopheles gambiae* s.l. with 307 individuals (29.6%). *Aedes aegypti* accounted for 93 individuals (9.0%). The collection consisted of 554 unfed mosquitoes, 112 blood-fed mosquitoes, 89 half-gravid mosquitoes, 168 gravid mosquitoes and 114 males. *Anopheles gambiae* s.l. comprised 185 unfed, 11 blood-fed, 7 half-gravid, 57 gravid and 47 male mosquitoes. *Culex quinquefasciatus* comprised 338 unfed, 88 blood-fed, 82 half-gravid, 84 gravid and 45 males. *Aedes aegypti* comprised 31 unfed, 13 blood-fed, 0 half-gravid, 27 gravid and 22 males. Species abundance differed significantly among the three mosquito taxa (F = 9.85, df = 2, 6, p = 0.012).

Table 3: Species Composition and Physiological Status of Mosquitoes Collected in Kwadon

Species	Unfed	Blood-fed	Half-gravid	Gravid	Male	Total	Relative Abundance (%)
Anopheles gambiae s.l.	185	11	7	57	47	307	29.6
Culex quinquefasciatus	338	88	82	84	45	637	61.4
Aedes aegypti	31	13	0	27	22	93	9.0
Total	554	112	89	168	114	1,037	100.0

ANOVA: F = 9.85, df = 2, 6, p = 0.012

Indoor and Outdoor Resting Distribution in Kwadon

The indoor and outdoor resting distribution of mosquitoes in Kwadon is summarized in Table 4. The table presents the abundance and mean number of mosquitoes recorded from indoor and outdoor resting sites. Indoor collections produced 758 mosquitoes compared with 279 mosquitoes collected outdoors. Indoor collections comprised 260 *An. gambiae* s.l., 449 *C. quinquefasciatus* and 49 *Ae. aegypti*. Outdoor collections comprised 47 *An. gambiae* s.l., 188 *C. quinquefasciatus* and 44 *Ae. aegypti*. The mean mosquito abundance was 252.7 ± 200.1 indoors and 93.0 ± 82.3 outdoors. The difference was statistically significant (t = 2.58, p = 0.046).

Table 4: Comparison of indoor and outdoor resting mosquito abundance in Kwadon

Species	Indoor	Outdoor
Anopheles gambiae s.l.	260	47
Culex quinquefasciatus	449	188

Species	Indoor	Outdoor
Aedes aegypti	49	44
Total	758	279
Mean ± SD	252.7 ± 200.1	93.0 ± 82.3

t = 2.58, p = 0.046

Discussion

The findings demonstrate a consistent presence of three mosquito taxa, Anopheles gambiae s.l., Culex quinquefasciatus and Aedes aegypti, in both Kuri and Kwadon, but their relative abundance differed between the two communities. Culex quinquefasciatus was dominant in both locations, accounting for 50.5% of mosquitoes collected in Kuri and 61.4% in Kwadon, whereas An. gambiae s.l. represented 45.4% and 29.6%, respectively. The observed differences suggest that mosquito community structure varied between the two locations despite their occurrence within the same regional climatic setting. *Culex quinquefasciatus* was the dominant mosquito in both locations, accounting for 50.5% of the collection in Kuri and 61.4% in Kwadon. The dominance of *Culex* in the present study may reflect the suitability of the local residential environment for culicine mosquitoes. *An. gambiae* s.l. constituted a substantial proportion of the mosquito population in both communities. It represented 45.4% of the total collection in Kuri and 29.6% in Kwadon. This is epidemiologically important because members of the *An. gambiae* complex are major malaria vectors in Nigeria (Adeleke et al., 2025).

The climatic context of the findings is important. North-Eastern Nigeria has experienced changes in rainfall and temperature patterns over recent decades. Ishaku et al. (2024) reported significant increases in maximum temperature across the region and spatially variable rainfall trends, including an increasing rainfall trend at Gombe. Evidence from other parts of Nigeria supports the relationship between meteorological conditions and mosquito abundance. Bello et al. (2025) reported significant relationships between meteorological variables and *Anopheles* larval occurrence in Epe and Orimedu.

Recent climate and malaria research provides further evidence for geographical heterogeneity. Carlson et al. (2026) found that temperature and extreme precipitation have affected childhood malaria prevalence differently across African regions. Recent research in Gombe North documented malaria prevalence of 62.41% across Gombe, Kwami and Funakaye Local Government Areas, with *P. falciparum* accounting for 92.71% of infections (Ishaku et al., 2026). The continued presence of a substantial *An. gambiae* s.l. population in Kuri and Kwadon therefore provides an important entomological context for malaria prevention in the state.

A notable finding was the greater number of mosquitoes collected from indoor resting sites than outdoor sites in both communities. In Kuri, 700 mosquitoes were collected indoors compared with 78 outdoors, while Kwadon yielded 758 indoor and 279 outdoor mosquitoes. This pattern indicates substantial indoor resting activity during the sampling period. However, the difference should be interpreted in relation to the collection methods used, because indoor mosquitoes were sampled using pyrethrum spray catches whereas outdoor mosquitoes were collected using an aspirator. Differences in sampling efficiency between these methods may therefore contribute to the observed distribution.

Limitation

Several limitations should be considered when interpreting the findings. First, climatic variables were not directly measured during mosquito collection; therefore, the study cannot establish a direct statistical association between temperature, rainfall, relative humidity and mosquito abundance. Second, mosquito identification was based on morphological characteristics, and Anopheles gambiae was therefore reported at the species-complex level. Third, the study provides a cross-sectional assessment and consequently represents mosquito composition and resting distribution during the sampling period rather than seasonal patterns. Finally, the observed indoor–outdoor distribution should be interpreted within the context of the sampling methods used for each resting environment. Future studies incorporating longitudinal sampling, direct environmental measurements and molecular species identification would provide a more comprehensive assessment of mosquito ecology in the study area.

Conclusion

This study documented the occurrence of *Anopheles gambiae* s.l., *Culex quinquefasciatus* and *Aedes aegypti* in Kuri and Kwadon, with Culex quinquefasciatus being the most abundant taxon in both communities. *Anopheles gambiae* s.l. also constituted a substantial proportion of the mosquito population, while blood-fed and gravid females indicated active feeding and reproductive activity during the sampling period. Mosquitoes were more frequently collected indoors than outdoors in both locations. These findings provide baseline entomological information for Kuri and Kwadon and support continued community-level surveillance. Because climatic variables were not directly measured, the climatic interpretation should be regarded as contextual rather than evidence of a direct climate and mosquito relationship. Based on these findings, it is recommended that routine entomological surveillance be strengthened in Kuri, Kwadon and surrounding communities to monitor changes in mosquito abundance, species composition and resting behavior. Indoor vector-control interventions should remain an important component of malaria prevention because a substantial proportion of mosquitoes collected during the study were found indoors, while environmental management should target potential mosquito breeding habitats, particularly stagnant water, blocked drainage, discarded containers and other artificial water-holding structures.

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